DOCUMENT RESUME

ED 244 552 HE 017 255

AUTHOR Arns, Robert G.; Urban, Patricia A.
TITLE Strategic Choices for Data Communications Systems.
PUB DATE Dec 83
NOTE 12p.; In: Information Resources and the Individual. Proceedings of the CAUSE National Conference (San Francisco, CA, December 11-14, 1983). Boulder, CO, CAUSE, 1984, p. 131-141. For the complete proceedings, see HE 017 245.
PUB TYPE Reports - Descriptive (141) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS College Administration; *Computer Oriented Programs; Computers; *Data Processing; Higher Education; *Information Networks; *Management Information Systems; *Microcomputers

ABSTRACT

Issues and strategies for developing a campus data communications system are discussed. It is suggested that individual microcomputer (MC) workstations will occasionally have a need for (1) access, via a data communications network, to a more powerful processor; (2) specialized software; (3) sophisticated output devices; (4) central data sets; or (5) communication with other work stations or with remote networks. This aspect of campus computing, the development of a local area network (LAN) to tie MCs to each other and to other computing resources, requires a number of choices about what form the LAN will take and how to bring it about. Attention is directed to network design considerations, network classifications, network topology (geometric pattern formed by the physical components of the network), network access, switching technologies, network protocols, data security and organizational development, implementation choices, and integrated voice and data communications. It is suggested that replacement of a telephone communication system with an integrated, high performance data and voice communication system provides an occasion for establishment of campus data communications capability. (Author/SW)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED244552

STRATEGIC CHOICES FOR DATA COMMUNICATIONS SYSTEMS

Robert G. Arns and Patricia A. Urban

The University of Vermont

Burlington, Vermont

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

This document has been reproduced as received from the person or organization originating it.

✓ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

CAUSE

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

Abstract: Colleges and universities have a responsibility and an opportunity to bring the power of information technologies to each student, staff, and faculty member in order that each may learn more rapidly and be more efficient and effective. This implies an intelligent workstation for each for computation, word processing, and record keeping as well as for such applications as simulation and computer based learning. These workstations will also occasionally have a need for access, via a data network, to a more powerful processor, or specialized software, or central data sets, or sophisticated output devices, or for communication with other workstations or with remote networks.

Issues arising in determining how to develop a data communications system to respond to these needs include: technical requirements (transmission rates, traffic capacity, network topology, switching architecture, communications protocols, and gateways to other networks); cost (and how to fund such a system); implications for coordination and (de)centralization of hardware and software selection and acquisition; deciding when to create a data network (avoiding commitment to obsolete or limiting technology); data security, information integrity, and organizational development. The various strategic choices that appear to be available are described. Replacement of a telephone system with an integrated, high performance data and voice communication system provides an occasion for establishment of campus data communications capability; the specific strategic choices inherent in this example are presented.

HE 017 255

Paper presented at the
CAUSE National Conference
(San Francisco, CA, Dec. 11-14, 1983)

With information technology penetrating every aspect of campus activities, it seems appropriate for each college and university to ask how far this revolution will go, and to examine what ought to be done and how soon. Closure of the planning process has eluded most of us, however, because of the rapid development of technology and the rapid evolution of aptitudes and attitudes with regard to the computer.

At the University of Vermont, central administrative computing currently uses an IBM 4341 mainframe, accessible through 160 terminals, and a small but growing number of IBM PC workstations. Central academic computing uses a DEC 2060 mainframe and a Harris 800 minicomputer, with 275 terminals, and a small but growing number of DEC Rainbow workstations. There is, in addition, an array of laboratory minicomputers, office word processors, and individually-owned personal computers.

Access to a computer is already a necessity for all students and faculty in certain disciplines. We anticipate that within three years each student in engineering and business administration will be required to have a personal computer and that all other students, all faculty, and many staff members will require access to computing resources. For most students, faculty, and staff members, the microcomputer (MC) will be the preferred instrument; word processing, personal recordkeeping, and most computations can be accomplished locally. But individual MC workstations will also occasionally have a need for access, via a data communications network, to a more powerful processor, or specialized software, or sophisticated output devices, or central data sets, or for communication with other work stations or with remote networks. This aspect of campus computing -- the development of a **local area network (LAN)** to tie MCs together and to other computing resources -- requires a number of choices about what form the LAN will take and how to bring it into being, and has other implications for campus information technologies.

NETWORK DESIGN CONSIDERATIONS

Communications technology is changing rapidly and consideration of the LAN presents various, often controversial, technical alternatives. The examination of technical alternatives must be tempered with practical considerations such as the applications to be supported, the devices to be interconnected, the physical characteristics of the site, and the resources and long-range plans of the organization. These issues must then be translated into technical specifications as a basis for analyzing the various alternatives along five important dimensions: reliability, convenience, efficiency, cost-effectiveness, and security.

The **reliability** of a network is the degree of uninterrupted, error-free service it provides. Routing, congestion control, and flow control algorithms are major factors as is the cost of providing backup equipment and alternate transmission paths. A critical factor in the design of a network is the **convenience** with which it can be used. The physical interface must be simple and straightforward so that access to the network can be established with a minimum of effort. Also, networks are used by persons with all levels of technical aptitude; ease of use may be critical to a network's success. **Efficiency** considerations mandate that the LAN be capable of operating with low link overhead by minimizing that portion of the transmitted message which is control information for facilitating communication between computers. **Cost effectiveness** introduces issues such as installation cost, ease of maintenance, and technological lifetime. **Security** is of prime importance; since no network can be absolutely secure, security features of hardware and software are an issue from the outset.

NETWORK CLASSIFICATIONS

Local area networks are classified according to the following characteristics:

- by medium (broadband cable, baseband cable, twisted pairs, fiber optic cable);
- by topology (star, ring, bus);
- by access method;
- by switching technology (circuit, message, packet); and
- by organization and control (centralized, decentralized, distributed).

NETWORK MEDIA: The standard transmission medium for tranditional (analog) telephone services is **twisted pair copper wire**. Two twisted pairs of copper wire also form the basis of the digital PBXs which compete with coaxial cable based networks for some LAN applications. Since a rate of 64,000 bps is required for transmission of digitized voice, this bandwidth, significantly higher than that of analog voice grade lines, also becomes available for transmitting data. After adding control information to the data stream, the available data rate is approximately 56 Kbps in most cases. This data rate is still unsuitable for handling file transfer applications which require transmission speeds in the 10 Mbps range.

By incorporating packet-switching techniques into conventional circuit-switched PBX designs, copper wire is capable of supporting the high traffic applications which have been previously found only in coaxial cable based networks. For example, current PBX technology can support 8,000 data stations operating in non-blocking mode at 64 Kbps each, producing an aggregate transmission capacity of 512 Mbps.

"Non-PBX" local area networks can also use twisted pairs; one such example is IBM's planned use of a token-passing ring which operates on twisted pairs with transmission speeds on the order of 4 Mbps.

Coaxial cable networks are used for digital applications requiring high bandwidth. A **baseband** coaxial cable utilizes a single information channel shared by many users (broadcast channel) utilizing time division multiple access (TDMA) techniques. Current transmission rates are in the 10 Mbps range. A **broadband** coaxial cable utilizes multiple channels over which information is multiplexed using any combination of TDM (time division multiplexing) and FDM (frequency division multiplexing). Broadband networks take advantage of the large bandwidth, 350 million Hertz (megahertz), found in cable television (CATV) systems. Data transmission rates in the hundred thousand megabit per second range are possible. Because of the utilization of multiple high-speed channels, both analog and digital transmission can be accommodated.

Fiber optic cable has bandwidth sufficient to transmit data at 10^{14} bits per second. Current technology supports data rates in the 100 Mbps range. Fiber optic cable has a major advantage over coaxial cable and twisted pairs in that it is dielectric, i.e., it is insensitive to electromagnetic interference.

NETWORK TOPOLOGY refers to the geometric pattern formed by the physical components of the network. A network **node** is a computer whose primary function is to switch data; a **link** is the physical connection between any two nodes, more commonly called the communications **channel**. A **path** is the logical connection between any two nodes. A computer whose

primary job is 'computing', rather than switching, is a **host**. Given this terminology, three widely implemented topologies will be examined: the star, the ring, and the bus.

The **bus** network consists of cable (the "bus") to which stations are attached by cable taps. Signals from the station emanate in both directions (thereby requiring a full-duplex medium) reaching every other station on the network. Decentralized control (lack of a master controller) provides for autonomous entry into the network. This, together with the fact that the nodes of a bus do no routing, account for the very high reliability of a bus network.

A **ring network**, a suitable topology for a simplex medium (transmitting in one direction only), consists of a circular chain of signal repeaters with cable links between repeaters. Stations communicate by launching messages into the ring via the repeaters which relay the messages around the ring to their destinations. Since the ring network, like the bus, utilizes a common transmission medium, the advantages are similar: full connectivity, broadcasting, decentralized control. The nodes of a ring do simple routing in that a node must decide whether to pass a message to the next station or to keep it.

The **star** network consists of a center or "hub" to which all stations are attached like the spokes of a wheel. Advantages of the star topology are: easy routing, since the hub knows the path to the other nodes; good security, because all access is controlled through a central point; and the ability to assign priority to selected nodes. The major disadvantage is that the operation of the entire network is dependent on the reliability of the central switch.

The bus and the ring are characteristic of the distributed designs of current coaxial cable based LANs. The star is characteristic of centralized local networks and long-distance networks where the objective is to provide terminal access to a central host.

NETWORK ACCESS: The most pervasive method for sharing a network medium is time division multiple access (TDMA); three widely used techniques for controlling access to a common channel on a timeshared basis are: reservation, polling, and contention schemes.

In **reservation** schemes, channel time is allocated according to a predetermined schedule. Each station has a time slot on the channel whether or not it has information to send.

In **polling** schemes, a master network controller allocates channel time on a request basis. Even when stations are idle, the controller continuously polls stations for requests for channel access. Polling schemes have the advantage of allowing the master controller to allocate channel usage equally or to give priority to a particular station. Polling is used in point-to-point networks.

In **contention** schemes, stations compete for channel access under rules that ensure orderly and equitable access. One method utilizes a **token**, a bit pattern which travels on the medium, to control access to the medium. If a node does not require access to the channel it allows the token to pass. If the node has a message to send, it takes the token, transmits the message and recreates the token at the end of the message. This technique is particularly suitable to ring topologies but can also be modified for use with the bus design. Token ring access schemes are sometimes referred to

as "distributed polling" techniques since the node initiates the action in transmitting the message.

A popular contention protocol developed by Xerox Corporation for use with the bus topology is called carrier sense multiple access with collision detection (**CSMA/CD**). In this scheme, a station must listen to see if there is traffic on the channel before attempting to send a message. If traffic exists, the station must wait. When the channel is clear, two stations which have been waiting may send messages simultaneously and their messages may collide. If collision occurs, both stations must cease transmitting and try to retransmit at a later time.

Time division schemes are not the only method for sharing access to a common medium. Bus topologies can also utilize frequency division multiplexing on broadband media. Stations that communicate at different frequencies can thus use the channel simultaneously.

SWITCHING TECHNOLOGIES: Telephone systems, whether analog or digital, utilize **circuit switching** technology which requires that a complete loop (circuit) be established prior to the start of communication. This loop then remains dedicated to the communication for the duration of the session. Circuit switching is optimal for voice communications where pauses are infrequent and delays cannot be tolerated; however, it is inefficient for most data communications since the channel is not being used when nothing is being transmitted.

Message switching technology, used in message telegram systems, utilizes a collection of physical circuits interconnected by switches that examine message control fields for determining flow control or routing. In this application, circuits are no longer dedicated for exclusive use by two stations. Message switching is more efficient in its use of channel capacity and, since messages are stored during periods of heavy usage, systems need not be designed to handle peak loads. Message switching, however, can cause unacceptable delays for real-time users.

Packet switching is an adaptation of message switching in which messages are broken up into blocks called "packets". Each packet has control information associated with it so that it can be transmitted across a network irrespective of other packets belonging to the same message. The delays and storage costs inherent in message switching are thereby eliminated. Packet switching computers are programmed to allocate a packet to the circuit with the least traffic.

Packet switching has been adapted to local area networks to handle the "bursty" communications that characterize the interactions between humans and computers in a real-time interactive environment. Pure packet switching has shortcomings in high data flow environments because of overhead (routing information on each packet) and because of the delay in arrival time of packets in the same message.

Steady-flow communications are common when two computers are directly connected to transfer digitized voice, files, or video information. Circuit switching has significant advantages in these environments. Local area networks are usually packet-switched, occasionally circuit-switched, but never message-switched. As computer and communications technologies merge, hybrid forms of circuit switching and packet switching will evolve to utilize the best features of both.

ORGANIZATION AND CONTROL: **Centralized** networks are usually star topologies which require a dedicated (point-to-point) link to each device on the network because there is no switching outside the master controller. Star networks are usually found in terminal-to-host applications and smaller networks where the functions of the switch (node) and the host are resident in the same computer. In a **decentralized** network, switching also occurs in one or more independent nodes. The distinction between a centralized and a decentralized network is one of organization only; although switching is distributed to the nodes, control is exercised by the central controller. The advantage of the decentralized organization is that some form of alternative routing may be established but not every path is duplicated. A fully **distributed** network implies the existence of at least two distinct paths between every pair of nodes. In fully distributed networks, control, as well as organization, is distributed to the nodes. Each node has the ability, based on a predetermined routing algorithm, to switch between links; algorithms are usually optimized for the most efficient use of resources.

NETWORK PROTOCOLS

The Open Systems Interconnection (OSI) model from the International Standards Organization (ISO), posits a seven-layer approach to network design which facilitates the interconnection of networks that are specific to a vendor or an application. The purpose of each layer is to offer certain services to the higher layers, without the higher layers having to know the details of the way in which those services are implemented. Communications with other layers within the same host are called **interfaces**. Rules and conventions for communication with the corresponding layer in another host are called **protocols**. In reality no actual communication takes place between layers; instead information is passed down through the layers to the bottom (physical) layer for actual transmission. The set of layers and protocols comprises the **network architecture**.

The **physical layer** (layer 1) is concerned with the electrical and procedural characteristics of transmitting bits over a physical medium. The **data link layer** (layer 2) is concerned with insuring error-free data transmission. In polled networks, link level protocols, such as IBM's SDLC and ISO's HDLC, are used to establish rules for framing and error correction for synchronous transmission. In local area networks, the polling protocols of point-to-point networks are replaced by packet broadcasting techniques. Carrier sense protocols used with bus topologies include collision detection protocols, collision-free protocols and limited-contention protocols. Protocols used with ring LANs include token-passing, contention protocols, and slotted ring protocols.

The **network layer** (layer 3) determines: (1) how packets are routed through the network; (2) what happens if congestion occurs; and (3), the nature of the interface of the **subnet** (layers 1 and 2) with the host. In the case of local networks, there is no network layer since packet routing is not performed. Consideration must still be given, however, to interfacing the subnet with the host.

The **transport layer** (layer 4) is the level at which host-to-host communication is performed. Its function is to pass data correctly between the session layer and the network layer. To accomplish this, it may establish one network connection, many network connections, or multiplex high volume data over a single network connection. Functions of the transport layer include naming and addressing, connection establishment, buffering, flow control, multiplexing, and error recovery.

The **session layer** (layer 5) is the user's interface with the network. The session layer establishes the connection and manages the dialogue between two users. The session layer may add application-oriented functions to the function supplied by the transport layer such as identification of users, checkpointing, and crash recovery. The **presentation layer** (layer 6) performs functions that are requested often enough to warrant general solutions, for example, encryption, code conversion, and format conversion and file transfer protocols. User programs comprise the **application layer** (layer 7). Issues which are relevant to this layer are distributed database systems and network operating systems.

A local area network implements only the first three layers of the OSI model. The older PBX circuit-switched designs were relatively easy to implement because they utilize only the first two layers of the OSI model; however, those PBX products which provide for high-speed transmission through shared medium access also reach the third layer.

The CCITT (Comite Consultatif Internationale de Telegraphique et Telephonique, a UN subcommittee) has developed international standards for layers 1, 2, and 3 of an interlink protocol for access to public packet-switched networks. These standards are collectively referred to as X.25. The first layer, the physical layer, is defined by the X.21 standard for analog and digital transmission; the second layer utilizes the CCITT-developed full-duplex Link Access Protocol (LAP); and the third or network layer provides for packet assembly, routing, and virtual circuit management. The X.25 standard and its extension, the X.75 standard for establishing a virtual circuit across multiple networks, may provide a strategy for tying LANs together using a backbone X.25 network. There appear to be practical problems, however, and the third generation digital PBX with high-speed data switching may be a more viable alternative for the interconnection of disparate LANs. The PBX can be the single point of communications control within an organization providing for the flexibility of access from any voice/data port and the integration of multi-vendor environments. Two implementations of this concept are possible: (1) the PBX may be the backbone, providing gateways for the interconnection of diverse LANs; or (2) the PBX itself may support a LAN architecture of its own, providing high-speed access to data stations on the switch as well as providing gateways to other LANs.

DATA SECURITY AND ORGANIZATIONAL DEVELOPMENT

Returning to the specific case of a university environment, the decision to create a LAN carries both opportunities and risks. **Data Security** -- maintaining data sets, software, and intellectual property free from unauthorized alteration or copying -- is a matter of concern because of the critical nature of information residing on hosts. Files such as the student data base, the accounting and payroll files, the library catalog, student papers, research data, and faculty manuscripts will be accessible through the LAN. The potential exists for fraud, theft, academic dishonesty, accidental erasure, etc.

A second area of potential problems, involving **information integrity** -- assuring that information derived using institutional data sets is an accurate and precise representation of the phenomenon it seeks to represent -- arises because the new information technologies are intrinsically personal and individual. These technologies can be expected to favor decentralization of power and authority. Decision makers throughout the organization will have timely and easy access to what we have traditionally thought of as institutional data. Quite justifiably, they will want to use these data themselves, locally, to make better decisions or to influence the decisions

of others. They will want to convert data to information and display the results of various calculations, projections, ratios, and trends. Because each will approach the conversion process with a particular set of skills, assumptions, definitions, and biases, the information produced will be of varying quality; there is considerable risk that decision makers will be misled or will mislead others.

Sensitive data sets can be protected to an acceptable degree by various measures that limit access to authorized persons. Although these techniques are reasonably well understood, most host systems in academic institutions are not adequately protected to withstand the added risk of connection to a LAN. Security safeguards should be developed in parallel with development of the LAN and be subject to continuing audit and evolution.

The threat to information integrity -- and the implied threat to soundness of management -- suggests the need for educational programs, technical support of local computing, and recognition that things can and should be done differently in a distributed environment than has been the case in an era of centralized computing. Administrators will need to learn non-procedural languages to facilitate the conversion of data to information.

The new information technologies and the creation of a LAN imply that all students, staff, and faculty should acquire certain computing skills. Overall, it will **not** be necessary or desirable that each person learn a programming language. We run the risk of steering more students toward high technology careers than can possibly be accommodated. However, the information technologies, including such things as videodisc, should be strange or forbidding to no educated person.

Faculty who wish to use information technologies effectively in their instruction will need an entirely different set of skills which encompass the nature of learning, the use of computers in the learning process, and the various ways in which computer-based learning differs from traditional classroom learning.

Every student, faculty member, and staff person will need a new perspective on their tasks. The sociological implications of the information technologies in our organizations are likely to be greater than we can hope to foresee. Most institutions have begun to develop the educational and intervention programs needed, but the widespread use of the MCs and their interconnection via a LAN will require attention to organizational development at a level that most of us have not begun to contemplate, plan, or implement.

IMPLEMENTATION CHOICES

It is tempting to delay the implementation of these changes because the technology will become faster, or cheaper, or to wait for others to make the mistakes. Many institutions will wait too long; the technology will always be improving and getting cheaper. The rate at which young people are adopting the MC makes it imperative that we bring information technologies promptly to center stage. The integration of the MC implies the establishment of a LAN and the attendant adjustments in the way we conduct our activities.

The technologies are expensive and complicated, seemingly beyond the means of most colleges and universities. The costs include the network medium (wiring the campus), the switching technology, and software and maintenance -- as well as the increased demand for central computing services, applica-

tions systems (e.g., library automation), workstations for faculty, staff, and administrators, and educational and organizational development programs.

There is also a significant risk that a particular set of technological strategies will prove to be limiting before the investment has run its course. Under these circumstances -- high investment required in a time of financial constraint for uncertain benefit -- the wisest choices are those that hold costs down, use multiple funding sources, and limit technological risk.

Given these conditions, the University of Vermont has adopted the following strategies and policies:

(1) Acquisition of MCs or workstations is funded locally, i.e., there is no central funding. Most departments have found the means through regular budgets or from grants and contracts; many faculty have bought MCs with personal funds.

(2) Central technical support, repair service, and discount purchase plans are provided for two types of MC. These workstations currently have preferential access to central computing services.

(3) Portions of centralized development resources are being redistributed to provide consulting support and training for persons in user offices in the use of non-procedural applications development tools.

(4) All hardware and software acquisition is subject to central approval. Units are advised concerning the advantages and disadvantages of various options in terms of quality of the product, central support, ease of integration with other systems, maintenance, and service.

(5) Issues of data security and information integrity are being addressed through control of access to sensitive data, training programs, limits on the form in which institutional data is released, and through use of a chargeback system to decrease frivolous use.

(6) In certain disciplines, students will be expected to buy their own MC when they enter. We will develop insurance, maintenance plans, and financial aid arrangements before this requirement is implemented.

(7) A library system is being developed that provides catalog access through terminals or workstations anywhere on campus (including dormitory rooms) through the LAN. The total cost of the library system, about $2 million over four years, will be sought through gifts and grants.

(8) We have begun planning for upgrading our central academic and administrative computer mainframes to meet the increased demand.

We expect to handle all of the foregoing within available resources. That leaves the LAN, a multimillion dollar investment, that we could not handle if it were not for a set of fortuitious circumstances.

INTEGRATED VOICE AND DATA COMMUNICATIONS

The fortuitious circumstances are the announcement of third-generation integrated voice and data switches coincident with the breakup of AT&T. The latter promises to result in escalating telephone charges for all of our institutions and instant obsolescence for those served by Centrex

exchanges. The former provides an opportunity to replace a telephone network owned by the Bell system with a LAN which will serve most data communications needs and provide better telephone service.

A third generation digital PBX has three basic characteristics: (1) distributed architecture, employing coaxial cable or fiberoptics to connect the central switch with the nodes in order to support high-volume communications; (2) integrated voice and data transmission; and (3) a non-blocking configuration, permitting all ports to be connected on a fully-available basis.

In considering this approach to establishment of a LAN, we set the following major technical requirements:

(1) Simultaneous voice and data transmission must be supported without reduction of port capacity or reduction in overall performance.

(2) The data switch must be capable of replacing the Gandalf PACX data switching system used in our Academic Computing Center and the network of leased lines and coaxial cable used to support remote communications with our Office of Administrative Computing.

(3) The data switch should provide for integration of the data communications environments of the campus. This includes accommodation of the communications protocols in use and protocol conversion to facilitate access to any host from any campus terminal or workstation.

(4) The data switch must be capable of supporting reasonable expectations of growth, in terms of number of connections (terminals, workstations) and increased traffic volumes associated with the eventual accommodation of a MC for each student and faculty member.

(5) Mandatory support of transmission speeds of 19.2 Kbps asynchronous and 56 Kbps synchronous.

(6) Mandatory support of transmission speeds up to 10 Mbps for host-to-host communications and for "downloading" of data files to workstations -- without significant impact on other simultaneous transmissions.

(7) The data switch must permit access to local as well as public packet-switched networks, specifically including support of the X.25 standard.

(8) The system must be based on a distributed architecture to permit the respective hosts to exercise network control over data traffic for purposes of network management, security, and trouble shooting.

(9) The switch manufacturer should be committed to providing a full range of system enhancements over time, as well as appropriate maintenance and support of the current system for at least ten years.

We believe that these specifications limit our technological risk to an acceptable level but, as an extra precaution, our RFP calls for an extra pair of coaxial or fiber-optic cables to be installed between all key campus buildings at the time of wiring the campus for the PBX system. Presumably that would permit some high-speed communications to take place on an a broadband or fiber-optic network, independent of the PBX network, if needed at some later time.

There appear to be two or three third generation switches that can meet most of these requirements. The good news is cost. Although we have not completed the bidding process, it appears that we can establish the LAN and have a better telephone system for about what it would have cost us to continue the obsolete Centrex service. The project calls for data connections in 1700 offices (3500 telephones) and data ports/phones in 2000 residence hall rooms. The initial capital cost is expected to be in the $8 million to $10 million range, including physical plant and contingency allowance. Bonding over a ten-year period, network access, startup costs, administration, power, and maintenance must be added to the initial capital cost; the grand total, over the ten-year period, amounts to about what we would expect to pay for our current inadequate telephone service over that period. We will own the system at the end of ten years and, while it is likely that we will want to replace the switching system at that time, the wiring and physical plant portion should have an extended life.

SUMMARY: We believe that universities should not postpone the establishment of a LAN to serve existing data communications needs and to interconnect the growing number of MCs. Although the costs, risks (of technological obsolescence, and to data security and information integrity), and organizational development requirements are not insignificant, we believe that the combination of a third-generation, high-performance, integrated voice and data communications system with ancillary broadband or fiber-optic cabling will provide the capability needed for a ten-year period and can be funded for what it would cost to maintain current telephone service alone.

ACKNOWLEDGMENTS

The authors are indebted to the members of the various telecommunications task forces, especially Arthur W. Brautigam, Communications Manager, William J. Young, Associate Vice President, Nancy L. Eaton, Director of Libraries, David G. Whitmore, Director, Academic Computing Center, and Norman A. Blair, Director, Budgeting and Institutional Studies, for the efforts that have led us to this point and for their contributions to this report.

REFERENCES

Kinnucan, P. "Local Networks Battle for Billion Dollar Market." **High Technology**, November/December 1982, pp. 64-70.

McNamara, J. **Technical Aspects of Data Communication, Second Edition**. Bedford, Mass.: Digital Press, 1982.

Nelson, J. "802: A Progress Report." **Datamation**, September 1983, pp. 136-152.

Pooch, U., Greene, W., Moss, G. **Telecommunications and Networking**. Boston and Toronto: Little, Brown and Company, 1983.

Tannenbaum, A. **Computer Networks**. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1981.